NASA Procedural Requirements

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COMPLIANCE IS MANDATORY

Planetary Protection Provisions for Robotic Extraterrestrial Missions

Responsible Office: Science Mission Directorate

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Preface

P.1 Purpose

This document sets forth NASA requirements applicable to robotic planetary flight programs. These requirements are necessary to enable the Science Associate Administrator to fulfill his/her responsibilities pertaining to planetary protection, as required by NPD 8020.7 (Biological Contamination Control for Outbound and Inbound Planetary Spacecraft). This document specifically addresses (1) the control of terrestrial microbial contamination associated with robotic space vehicles intended to land, orbit, flyby, or otherwise encounter extraterrestrial solar system bodies, and (2) the control of contamination of the Earth and the Moon by extraterrestrial material collected and returned by robotic missions.

P.2 Applicability

a. The provisions of this document apply to NASA Headquarters, NASA Centers, including Component Facilities, and to the Jet Propulsion Laboratory as specified in its contract.
b. The requirements of this document apply to all robotic missions that may encounter other solar system bodies, including those to and from the Earth's Moon, and to all robotic solar system exploration missions returning extraterrestrial samples to the Earth or the Moon.
c. This document is specifically not applicable to the following:

1. terrestrial (Earth-orbital) missions.
2. human missions, except for Shuttle-launched, but otherwise robotic, planetary missions.

d. NASA officials responsible for applicable flight programs and projects will impose these requirements in such directives or contractual instruments as may be necessary to ensure their implementation.

P.3 Authority

NPD 8020.7, Biological Contamination Control for Outbound and Inbound Planetary Spacecraft

P.4 References

Biological Contamination Control for Outbound and Inbound Planetary Spacecraft, NPD 8020.7, National Aeronautics and Space Administration, Washington, D.C. (1999).

NASA Standard Procedures for the Microbial Examination of Space Hardware, NPR 5340.1. National Aeronautics and Space Administration, Washington, D.C. (1980).

P.5 Cancellation

This document replaces NPR 8020.12B, dated April 16, 1999.

/s/ A.V. Diaz
Associate Administrator for
Science Mission Directorate

Chapter 1. Introduction

1.1 Relationship to Planetary Flight Project's Project Plan

a. NPD 7120.4, Program/Project Management, requires the preparation of a Project Plan during the formulation of any flight project. The Project Plan specifies how the project will incorporate any required planetary protection planning. The scope of related information to be included and the level of detail will vary with each Project Plan. In general, planetary protection planning should be described so as to be consistent with other elements of the Project Plan.
b. The management approach is a part of each Project Plan and should include the broad management aspects of the planetary protection activities of the project. Required planetary protection planning documents, as specified in Chapter 2 of this document, should be referenced in the Project Plan.

1.2 Planetary Protection Categorization of Missions

Each planetary mission will fall into one or more categories based on the planetary protection priorities of each extraterrestrial solar system body and the mission plan. Planetary protection priorities and corresponding mission categories are given in Table 1. Each category has different planetary protection requirements, as defined in Chapter 2 of this document. Mission categorization is determined by the Planetary Protection Officer (PPO) as discussed in 2.1.1.b.

1.3 Deviations

Any deviation from the requirements of this NPR is subject to the review and written approval of the PPO, NASA Headquarters. Procedures for requesting deviations are given in 2.4.

1.4 Revisions

This revision incorporates changes and improvements and reflects current planetary protection requirements for robotic missions. Further revisions of this document will be issued as new information warrants.

Table 1. Planetary Protection Mission Categories

Planetary Targets Priority	Mission Type	Mission Category
Not of direct interest for understanding the process of chemical evolution, or where exploration will not be jeopardized by terrestrial contamination. No protection of such planets is warranted and no requirements are imposed.	Any	I
Of significant interest relative to the process of chemical evolution but only a remote chance that contamination by spacecraft could jeopardize future exploration.	Any	II

Of significant interest relative to the process of chemical evolution and/or the origin of life or for which scientific opinion provides a significant chance of contamination which would jeopardize a future biological experiment or exploration program(s).	Flyby, Orbiter	III
Of significant interest relative to the process of chemical evolution and/or the origin of life or for which scientific opinion provides a significant chance of contamination which would jeopardize biological experiments or exploration program(s).	Lander, Probe	IV
Any Solar System Mission	All Earth-Return	V

Notes: 1) For missions that target or encounter multiple planets, more than one category may be specified for planets targeted or encountered.

2) For missions utilizing gravity assist by means of a flyby of another planet, requirements will usually be those for the target requiring the higher degree of protection.

2.1 General Mission Requirements

2.1.1 NASA Missions

a. Specific planetary protection requirements for each planned mission will be determined by the NASA PPO, in accordance with this document, and consistent with the policy and guidelines of the Committee on Space Research (COSPAR), recommendations of the Space Studies Board of the National Research Council (NRC), and advice from the NASA Advisory Council.
b. Requests for categorization of missions and associated mission requirements shall be submitted to the PPO during the mission design phase (before the completion of the draft Planetary Protection Plan) by the mission Project Manager. Such correspondence shall be accompanied by a mission description and shall include a request and justification for a specific mission categorization (a category-specific listing of target body/mission types is provided in Appendix A for guidance in preparing this request). The PPO will respond, in writing, with the appropriate categorization, conveying such explanatory information or supplemental conditions as may be appropriate. Subsequent approval of a mission's Planetary Protection Plan will constitute formal categorization of the mission.

2.1.2 Requirements for NASA Instruments on non-NASA or non-U.S. Missions

a. Planetary Protection guidelines also apply to the flight of NASA instruments and/or experiments manifested on non-NASA or non-U.S. spacecraft. In general, NASA will approve the flight of NASA-developed instruments and/or experiments on non-U.S. planetary spacecraft only if the launching organization adheres to the COSPAR-approved planetary protection policy and its requirements.
b. For flight on non-NASA spacecraft, U.S. instruments and/or experiments will be delivered to the agency or project of the sponsoring organization or country in compliance with the applicable planetary protection requirements and in a fashion compatible with specified procedures and activities. Instrument projects anticipating flights on non-NASA spacecraft can receive preliminary guidance at any point by submitting a request to the PPO outlining the nature of the instrument(s) to be flown and details of the anticipated flight opportunity.
c. For non-U.S. spacecraft, the U.S. instrument/experiment developer shall submit a Planetary Protection Plan (consistent with the mission categorization) to the NASA PPO for approval. The plan shall define the planetary protection requirements to be implemented and outline the general procedures to be employed to meet those requirements. Instrument projects anticipating flights on non-NASA spacecraft can receive preliminary guidance by submitting a request to the PPO outlining the nature of the instrument(s) to be flown and details of the anticipated flight opportunity. During development and delivery of the instruments/experiments, monitoring of the implementation and certification of planetary protection requirements will be the sole responsibility of the agency or project of the sponsoring country. The NASA PPO may agree with the launching agency or project to share in or assume such responsibility by separate arrangement.

2.2 Implementation Requirements for U.S. Missions

A summary of implementation requirements is provided in Table 2.

Table 2. Summary of Planetary Protection Implementation Requirements by Mission Category

Mission Category	Implementation Requirements
I (Any)	Documentation only.
II (Any)	Documentation only.

III (Flyby, Orbiter)	Impact avoidance and contamination control including: cleanroom assembly, microbial reduction, trajectory biasing.
IV (Lander, Probe)	Impact avoidance and contamination control including: cleanroom assembly, microbial reduction, trajectory biasing, organics archiving.
V "Unrestricted Earth return" "Restricted Earth return"	As defined by appropriate outbound mission Category I-IV. No inbound planetary protection requirements. Impact avoidance and contamination control including: clean room assembly, microbial reduction, trajectory biasing, organics archiving, containment of sample, breaking chain of contact with target planet, sample containment and biohazard testing in receiving laboratory (continuing monitoring of project activities, pre-project advanced studies and research, as needed).

2.2.1 Category I Missions

Certification of a mission as Category I relieves a project of all further planetary protection requirements, including further documentation. Solar system missions/bodies classified as Category I are listed in Appendix A.

2.2.2 Category II Missions

The planetary protection requirements are for documentation only. Preparation of a brief Planetary Protection Plan is required for these flight projects in order to state intended or potential impact targets and detailing impact strategies. Projects will also provide Pre- and Post-Launch Reports and an End-of-Mission Report that will provide the location of impact, if such an event occurs. The combinations of solar system bodies and types of missions classified as Category II are listed in Appendix A.

2.2.3 Category III Missions

Planetary protection requirements will consist of documentation (more involved than Category II) and some implementing procedures, including trajectory biasing, the use of cleanrooms during spacecraft assembly and testing, and possibly microbial reduction. An inventory of bulk constituent organics is required if the probability of impact is considered significant. The combinations of solar system bodies and types of missions classified as Category III are listed in Appendix A. Detailed requirements and associated specification sheets for Category III missions to selected solar system bodies are set forth in Appendices A and B, respectively.

2.2.4 Category IV Missions

Planetary protection requirements include detailed documentation (more involved than Category III), including bioassays to enumerate the microbial burden, a probability of contamination analysis, an inventory of the bulk constituent organics, and an increased number of implementing procedures. These implementing procedures may include trajectory biasing, cleanrooms, microbial reduction, possible partial sterilization of the direct contact hardware and a bioshield for that hardware, and, in some instances, system (lander/probe) sterilization. The combinations of solar system bodies and types of missions classified as Category IV are listed in Appendix A. Detailed requirements and associated specification sheets for Category IV missions to selected solar system bodies are set forth in Appendices A and B, respectively.

2.2.5 Category V Missions

This category comprises all Earth-return missions. The concern for these missions is the protection of the terrestrial system, the Earth and the Moon. The Moon must be protected from the potential for back contamination to retain freedom from planetary protection implementation requirements on Earth-Moon travel. For solar system bodies deemed by scientific opinion to have no indigenous life forms, a subcategory "Unrestricted Earth return" is defined.

Missions in this subcategory have planetary protection requirements on the outbound phase only, corresponding to the category of that phase (typically Category I or II). Requests for categorization as "Unrestricted Earth return" must be submitted to the PPO by the Project Manager when mission categorization is requested. After discussions with the PPO, a memorandum will be submitted by the PPO to the Science Associate Administrator requesting "Unrestricted Earth return" certification for the mission. For all other Category V missions, in a subcategory defined as "Restricted Earth return," the highest degree of concern is expressed by the prohibition of destructive impact upon return, the need for containment throughout the return phase of all returned hardware which directly contacted the target body and/or any unsterilized material from the body, and the need for containment of any unsterilized sample collected and returned to Earth. After the flight mission there is a need to conduct, under strict containment and using the most effective techniques, timely analyses of the unsterilized sample collected and returned to Earth. If any sign of a non-terrestrial replicating entity is found, the returned sample must remain contained unless treated by an effective sterilizing procedure. Category V concerns are reflected in requirements that encompass those for Category IV plus the continued monitoring of related project activities, studies, and research. Documentation requirements are detailed in 2.3.1 through 2.3.6. Specific Category V requirements for selected solar system bodies are included in Appendix A.

2.3 Planning and Documentation

2.3.1 Planetary protection documents shall be prepared as part of the formal documentation for the project and shall be submitted via the applicable Program Executive to the PPO for approval. Schedules for drafts and submission of the required documentation for all mission categories are detailed in 2.6. A summary of planning and documentation requirements is presented in Table 3.

Table 3. Planning and Documentation Requirements by Mission Category

Mission Category	Planning and Documentation
I (Any)	1. Certification of Category I mission, only
II (Any)	1. Planetary Protection Plan 2. Pre-Launch Planetary Protection Report 3. Post-Launch Planetary Protection Report 4. End-of-Mission Report
III (Flyby, Orbiter)	1. Planetary Protection Plan 2. Pre-Launch Planetary Protection Report 3. Post-Launch Planetary Protection Report 4. Organics Inventory 5. End-of-Mission Report
IV (Lander, Probe)	1. Planetary Protection Plan 2. Pre-Launch Planetary Protection Report 3. Post-Launch Planetary Protection Report 4. End-of-Mission Report 5. Organics Inventory
V "Unrestricted Earth return" "Restricted Earth return"	1. Documentation for outbound phase 2. Certification of Unrestricted Earth return 1. Planetary Protection Plan including outbound phase and Earth Safety Analysis Plan 2. Pre-Launch Planetary Protection Report 3. Post-Launch Planetary Protection Report 4. Earth Pre-Entry Report 5. Sample Pre-Release Report 6. End-of-Mission Report

2.3.2 In addition to the above, any mission other than Category I intending to enter an extended mission period (beyond the mission duration approved in the Planetary Protection Plan) must submit a Planetary Protection Extended Mission Report, analogous to a Pre-Launch Report, on a schedule per 2.6. In this document, the status of planetary protection compliance during the flight mission and the health of the spacecraft must be reviewed and summarized. The

demonstration of compliance with all applicable planetary protection requirements during the extended mission and the results of any necessary analysis for the extended mission must also be provided.

2.3.3 Summary Documentation Requirements

a. Category I missions:

1. Certification of mission as Category I relieves a project of all further planetary protection requirements.

b. Category II missions:

1. A Planetary Protection Plan outlining intended or potential impact targets.
2. Brief Pre- and Post-Launch Planetary Protection Reports detailing impact avoidance strategies.
3. End-of-Mission Report providing the final actual disposition of launched hardware and impact location.

c. Category III missions:

1. A Planetary Protection Plan that details the planned approach to compliance with planetary protection requirements, including subsidiary plans.
2. A Pre-Launch Planetary Protection Report which documents that all requirements have been met (note that an inventory of bulk constituent organics, if the probability of impact is significant, must be included in the Pre-Launch Planetary Protection Report).
3. A Post-Launch Planetary Protection Report that updates the Pre-Launch Planetary Protection Report.
4. An End-of-Mission Report which provides a complete report of compliance, the final actual disposition of launched hardware, and, in the case of accidental impact, the probable location of impact and its region of uncertainty.

d. Category IV missions:

1. A Planetary Protection Plan that details the planned approach to compliance with the implementation requirements (e.g., mission description, probability estimates, microbial burden estimates, contamination analysis plan, assay plan, microbial reduction plan).
2. A Pre-Launch Planetary Protection Report that documents the degree to which all requirements have been met and that must include the values of the microbial burden at launch and the organics inventory.
3. A Post-Launch Planetary Protection Report that updates the Pre-Launch Planetary Protection Report.
4. An End-of-Mission Report that provides a complete report of compliance and the final disposition of all launched hardware.
5. An inventory of bulk constituent organics that includes:

i. Parts lists, material lists, and other program documentation containing data relevant to organic material identification that are prepared by a flight project to specify and control the materials that are included in a vehicle destined for planetary landing.
ii. The locations of landings and impact points (determined and defined as accurately as mission constraints permit) of major components of space vehicles on the planet surface,
iii. Estimates of the condition of each landed spacecraft to assist in calculating the spread of organic materials.

e. Category V missions. Missions categorized as "Unrestricted Earth return" have outbound phase requirements, only (see above). Missions categorized as "Restricted Earth return" require:

1. A Planetary Protection Plan, including outbound phase requirements, if any, and an Earth Safety Analysis Plan.
2. A Pre-Launch Planetary Protection Report, including outbound phase requirements, if any, that must document the degree to which all Earth-return requirements to be attained prior to launch have been met.
3. A Post-Launch Planetary Protection Report, including outbound phase requirements, if any, to update the Pre-Launch Planetary Protection Report with respect to Earth-return requirements.
4. After sample collection, a report analogous to the outbound phase launch reports: i.e., an Earth Pre-Launch Report.
5. An Earth Pre-Entry Report demonstrating readiness to enter the Earth's atmosphere in compliance with planetary protection requirements.
6. An End-of-Mission Report to address compliance with requirements for the protection of the Earth's biosphere and detailing the transfer of the samples to an appropriate containment facility.
7. A Sample Pre-Release Report to provide verification of sample analysis procedures subsequent to the End-of-Mission and demonstrating that any planned sample release will not harm the Earth's biosphere.

2.3.4 Planetary Protection Plan (Categories II-V)

2.3.4.1 General Outline

a. Except for Category I missions, each planetary flight project shall prepare a Planetary Protection Plan according to the schedule outlined in 2.6. The Planetary Protection Plan shall be the primary planning document describing how a planetary flight project will meet its planetary protection requirements. The Planetary Protection Plan shall indicate planned conformance to those requirements and shall include, as a minimum, the items given in the following outline (see below). It is recognized that each project will prepare various other documents that may adequately cover some of the topics in the outline (e.g., the Project Plan may thoroughly cover the subject of Planetary Protection Management). In such instances, it is suggested that the Planetary Protection Plan include only the major aspects of the topic and that free reference be made to the basic project documents that provide specificity.
b. The Planetary Protection Plan shall include, but is not limited to, the items given in the following outline:

A. General

1. Introduction
2. NASA Planetary Protection Constraints

a. Designation of Mission Category
b. Planetary Protection Specifications

B. Planetary Protection Management and Organization

1. Organization Description
2. Responsibilities and Relationships
3. System Interface Management
4. Contractor Management
5. Data Management

C. Documentation

1. Identification of References and Applicable Documents

D. Facilities

1. Identification and Description of Controlled Facilities
2. Activities Performed
3. Hardware Affected

E. Schedules

1. Identification of Milestones
2. Preliminary Schedules

In addition, the following subsidiary plans shall be prepared when required for the particular category assigned:

1. Contamination Analysis Plan
2. Microbiological Assay Plan
3. Microbial Reduction Plan
4. Earth Safety Analysis Plan

c. The following paragraphs address specific Category II-V Mission Planning and Documentation requirements.

3. For Category II missions, sections B (Planetary Protection Management and Organization) and D (Facilities) of the Planetary Protection Plan may be omitted. No subsidiary plans are required.
4. For Category III missions, all of the items listed in 2.3.4.1.b. A thru E shall be included. Subsidiary plans shall be provided as appropriate. Probability of impact and planned contamination control procedures shall also be directly addressed in the Planetary Protection Plan for Category III missions. If the mission involves an orbiter, the minimum planned periapsis altitude and planned final disposition of the hardware shall be noted.
5. For Category IV missions, all of the items listed in 2.3.4.1.b. A thru E describing the Planetary Protection Plan must be addressed. In addition, the Contamination Analysis Plan and the Microbiological Assay Plan (subsidiary plans) are required. If any microbial reduction procedures are contemplated, the Microbial Reduction Plan is also

required. These subsidiary plans are described in 2.3.5.
6. Planning and documentation requirements for Category V missions, including required subsidiary plans, are described in 2.3.9.

2.3.5 Detailed Description of Subsidiary Plans (Categories III-IV)

2.3.5.1 Contamination Analysis Plan (Categories III and IV)

a. This document shall be the primary planning document covering the major analyses that are performed by the project and ultimately used to demonstrate to the PPO that the project is meeting the planetary protection requirements on microbial burden.
b. This plan should include, but not be limited to, the items given in the following outline:

A. General

1. Introduction
2. Rationale and Assumptions

B. Potential Contaminating Sources
C. Microbial Burden Estimate Model

1. Contamination Sources Analysis

a. Analytical Techniques
b. Assumptions
c. Substantiation of Parameter Values

2. Allocation Model

a. Systems Allocations (Spacecraft, Launch Vehicle, etc.)
b. Subsystem and Lower Level Allocations

D. Analysis Documentation

2.3.5.2 Microbiological Assay Plan (Category IV)

a. a. The Microbiological Assay Plan shall identify the space vehicle hardware, facilities, and associated environments which are subject to microbiological assay and shall describe the rationale, concepts, and detailed procedures pertaining to such assays. The plan shall describe the microbiological quality assurance procedures used to ensure validity of the assay results.
b. b. The plan shall include, but not be limited to, the items given in the following outline:

A. General

1. Introduction
2. Rationale and Assumptions

B. Assay Methods

1. Utilization of NPR 5340.1, NASA Standard Procedures for the Microbiological Examination of Space Hardware. Alternative procedures, consistent with mission and life detection objectives, may be proposed by the Project for approval by the PPO.
2. Laboratory Assay Procedures
3. Sampling Procedures
4. Provision for Verification Assays
5. Quality Assurance Provisions

C. Facilities

1. Controlled Facilities

a. Assay Laboratories
b. Hardware Areas

2. Uncontrolled Facilities

a. Monitoring
b. Environmental Estimates

D. Space Hardware (Flight) Assay and Control

1. Identification
2. Hardware Exceptions
3. Contingency Planning

E. Assay Data

1. Traceability
2. Analysis and Interpretation
3. Management and Handling

2.3.5.3 Microbial Reduction Plan (Category IV)

a. A Microbial Reduction Plan shall be submitted for planetary missions involving hardware elements that must have their microbial burden reduced to a specified or measured (assayed) level.
b. The Microbial Reduction Plan shall include, but not be limited to, the items in the following outline.

A. General

1. Introduction
2. Rationale and Assumptions

B. Spacecraft Hardware Subject to Microbial Reduction Processes

1. Identification
2. Exceptions

C. Process Analysis

1. Analytical Techniques
2. Assumptions
3. Process Parameters
4. Process Modification

D. Process Verification and Control

1. Process Description and Boundaries
2. Process Qualification
3. Equipment and Facilities Qualification
4. Acceptance Criteria
5. Process Interruption and Modification
6. Quality Assurance Provisions

E. Maintaining Reduced Microbial Level

1. Monitoring/Assaying
2. Using Microbial Barriers
3. Controlling Macro-organisms (Insect, Animal, etc.)
4. Contingency Planning

2.3.6 Pre-Launch Planetary Protection Report (Category II-V)

2.3.6.1 General Report Requirements

a. The Pre-Launch Report is the basic document used by a flight project to provide verification to the PPO that planetary protection requirements have been met (to the issue date of the document) and that the project will continue to satisfy planetary protection requirements throughout the mission.
b. This document shall include, but not be limited to, the following information. This information may be included

as a part of the document or referenced in the document. Reference documents may be submitted to the PPO as they are published. The following information is required:

1. A demonstration that all planetary protection constraints and requirements as noted in the Planetary Protection Plan will be met.
2. Identification of all approved planetary protection deviations (see 2.4) from the Planetary Protection Plan.
3. Summaries of potentially significant violations of planetary protection requirements or procedures that could occur and thorough discussion of contingency planning associated with each potential event.

2.3.6.2 Mission Category Specific Requirements

a. For Category II missions, a report on any required contamination control measures shall be provided.
b. For Category III missions, the following information shall be provided:

1. Calculations of microbial burden estimates.
2. Report on required contamination control measures.
3. Calculations of probability of impact.
4. Organic materials inventory.

c. If the mission involves the use of hardware subject to microbial reduction processes, the verification that such processes have been properly applied shall be included. If the mission involves an orbiter as part of the launched hardware, the issue of orbital lifetime shall also be addressed.
d. For Category IV missions, the requirements include the same information as for Category III. Additionally, information must be provided detailing the microbial reduction procedures employed and documentation supporting the results of the process.

2.3.7 Post-Launch Planetary Protection Report (Category II-V)

After the launch of a planetary vehicle, the flight project shall submit to the PPO a "Post-Launch Planetary Protection Report." This shall be a brief summary document based on the "Pre-Launch Planetary Protection Report" but updated to include the effects of launch and early post-launch events. It shall demonstrate compliance with the overall planetary protection requirements through these early mission events.

2.3.8 End-of-Mission Report (Category II-V)

a. At the formally declared "end-of-mission," a report shall be provided which documents the degree to which the mission has met the planetary protection requirements throughout the complete mission and reports the final disposition of all launched hardware. For the record, the report shall also document instances where planetary protection requirements were not fully met, including reasons for any deviations and the projected consequences to the degree they are known.
b. For all Category II and III missions, an inventory of organic materials must also be provided in the End-of-Mission Report for any spacecraft hardware which unintentionally impacted any solar system body.

2.3.9 Category V Missions, Planning, and Documentation

2.3.9.1 Outbound Phase

For the outbound phase of Category V missions, the planning and documentation requirements are those appropriate to the mission if there were no Earth-return phase.

2.3.9.2 Inbound Phase

Earth-return missions certified for "Unrestricted Earth return" have no formal implementation requirements. Missions certified "Restricted Earth return" will complete the following plans:

a. Earth Safety Analysis Plan

The Earth Safety Analysis Plan shall be the primary planning document covering the Earth-return portion of the mission. Its purpose is to demonstrate to the PPO that the project is meeting its planetary protection requirements. This plan shall include, but not be limited to, the items given in the following outline:

A. General

1. Identification
2. Rationale and Assumptions

B. Potential Contaminating Sources

1. Sample Containment Approach
2. Decontamination Approach (if required)
3. Earth Entry Plan

C. Probability of Contamination Model

1. Mission Probability of Contamination Equation
2. Critical Parameters
3. Contamination Sources Analysis

a. Analytical Techniques
b. Assumptions
c. Substantiation of Parameter Values

4. Probability of Contamination Allocation Model

a. Level of Risk (provided to the Project by the PPO)
b. System Allocations (Return Capsule, Return Vehicle, etc.)

D. Analysis Documentation

b. Earth Pre-Return Report

The "Earth Pre-Return Report" is a document patterned after the Planetary Protection Plan used by a flight project to provide verification to the PPO that planetary protection requirements outlined in the Earth Safety Analysis Plan have been met and that the project can and will continue to satisfy them throughout the Earth-Return portion of the mission.

c. Earth Pre-Entry Report

After the launch of the Earth-return portion of the mission, the flight project shall submit to the PPO an "Earth Pre-Entry Report." This shall be a document that updates the "Earth Pre-Return Report," to include the effects of launch and early post-launch events. It shall indicate how the mission meets the overall planetary protection requirements.

d. End-of-Mission Report

In addition to the information provided consistent with outbound phase requirements, at the formally declared "end-of-mission," a report shall be provided which documents the degree to which the mission has met its planetary protection requirements through landing and delivery of sample to containment in a Sample Receiving Facility. Special attention shall be paid to the Earth's biosphere safety requirements of the mission.

e. Sample Pre-Release Report

Before an extraterrestrial sample is released to the general scientific community for investigation, a "Sample Pre-Release Report" shall be prepared certifying that, if released, the sample will not harm the Earth's biosphere. This report verifies that biohazard and life detection protocols have been executed and that samples are free of hazard to the Earth's biosphere and are, therefore, safe for release.

2.4 Requests for Deviations

a. Deviations from the requirements of this NPR may be requested by proposing alternative(s) in distinct and separately identified part(s) of the Planetary Protection Plan (or other applicable subsidiary plan). Approval of the Planetary Protection Plan by the PPO will constitute written approval of proposed deviations so incorporated.
b. Deviations that are requested subsequent to the formal approval of the Planetary Protection Plan (or other applicable subsidiary plans) may be obtained by petitioning the PPO in writing. Such petitions shall be transmitted via established program management channels. Requests shall describe the need for a deviation and the justification to support the request. Such requests shall include the impact of the requested change on the original analyses and resulting changes, if any, in the category of the mission. The degree of compliance with all requirements shall be addressed. This requirement also applies to post-launch changes (see 3.1.5.2). The PPO will respond, in writing, to each request. Changes involving major deviations within Category V will require approval by the Science Associate Administrator. Each approved deviation shall be documented separately, for the record, in the End-of-Mission Report.

2.5 Reviews

2.5.1 General

a. For Categories III, IV, and V (Restricted Earth return) several reviews will be held to assure that planetary protection activities are proceeding properly. At a minimum, these will include the reviews listed in Table 4. Additional formal and informal reviews may be held as warranted and as requested by the PPO.
b. Generally, it is intended that formal planetary protection reviews be scheduled near the dates of project reviews or other technical reviews. Alternatively the formal Planetary Protection reviews specified (see Table 4) may be incorporated as a segment of a broader project review.
c. The PPO or designee shall be in attendance at these reviews.

Table 4. Planetary Protection Review Requirements

Mission Category	Required Review
I (Any)	None
II (Any)	Project Planetary Protection Review (PPO Option)
III (Flyby, Orbiter)	1. Project Planetary Protection Planning Review 2. Pre-Launch Planetary Protection Review 3. Launch Readiness Review
IV (Lander, Probe)	1. Project Planetary Protection Planning Review 2. Pre-Launch Planetary Protection Review 3. Launch Readiness Review
V "Unrestricted Earth return" "Restricted Earth return"	No further reviews beyond those levied for outbound phase of the mission as appropriate (see categories I-IV) 1. Project Planetary Protection Planning Review 2. Pre-Launch Planetary Protection Review 3. Launch Readiness Review 4. Earth Return Pre-Launch Review 5. Earth Safety Analysis Review 6. Returned Sample Release Review

2.5.2 Project Planetary Protection Planning Review (Categories II-V)

a. At the request of either the PPO or the project's authorized representative, a Planetary Protection Planning Review may be held when the draft version of the project's Planetary Protection Plan and the subsidiary plans are near completion. The purpose of conducting this review at this time is to enable the PPO to suggest such changes

to the project's planetary protection planning as are necessary for the formal version of the Planetary Protection Plan to be approved without major change or delay.

b. The content of this review will be developed from discussions between the PPO and various organizational elements of the project. Action items which may result from this review shall be tracked and closed out by the same procedures the project uses for resolving action items resulting from other formal technical reviews. The PPO may require that all action items resulting from this review be closed out before formal approval of the Planetary Protection Plan. Approval of the mission's Planetary Protection Plan constitutes formal categorization of the mission for planetary protection purposes.

2.5.3 Pre-Launch Planetary Protection Review (Categories III-V)

Prior to launch, a "Pre-Launch Planetary Protection Review" shall be conducted for all missions assigned to Categories III, IV, and V. The PPO shall conduct this review to ascertain whether a project has, to that date, met its planetary protection requirements. As a part of this review, the PPO will also examine, in detail, the planetary protection activities accomplished prior to this review as well as those remaining prior to launch. The "Pre-Launch Planetary Protection Report" (see 2.3.3) shall form the framework for this review.

2.5.4 Launch Readiness Review (Categories III-V)

Various events detrimental to planetary protection could occur subsequent to the Pre-Launch Planetary Protection Review and prior to actual launch of the vehicle. In order to ensure that planetary protection requirements continue to be met, the PPO (or designated alternate) shall participate in the project's formal Launch Readiness Review, the agenda of which shall include planetary protection as a topic. Significant planetary protection events, problems, changes, open action items, etc., that have occurred since the Pre-Launch Planetary Protection Review, shall be addressed.

2.5.5 Earth Return Pre-Launch Review (Category V, "Restricted Earth return")

Prior to launch of the Earth return portion of a Category V mission, an Earth Return Pre-Launch Review shall be conducted for all missions assigned to Category V. The PPO shall conduct this review to ascertain that a project has, to that date, met its planetary protection requirements. As a part of this review, the PPO will also examine, in detail, the planetary protection activities accomplished prior to this review as well as those remaining prior to launch. The formally released edition of the "Earth Pre-return Report" (see 2.3.9.2.b) shall form the framework for this review.

2.5.6 Earth Safety Analysis Review (Category V, "Restricted Earth return")

Prior to committing a spacecraft to the Earth return portion of its mission, the PPO shall conduct an Earth Safety Analysis review to determine whether all planetary protection requirements have been met and will continue to be met throughout the duration of the mission. The formally released document "Earth Safety Analysis Plan" (see 2.3.9.2.a), as updated by the Earth Pre-Entry Report (see 2.3.9.2c), shall form the framework for this review.

2.5.7 Returned Sample Release Review (Category V- Restricted Earth return)

Prior to release of an extraterrestrial sample, or portions of the sample, for study elsewhere, the PPO shall conduct a returned Sample Release Review. This review is to ascertain that all planetary protection requirements, including the execution of prescribed life detection and biohazard protocols have been met. The formally released document "Sample Pre-Release Report" (see 2.3.9.2.e), or an appropriate subset, shall form the framework for the review.

2.6 Schedules of Documentation and Review

Table 5 shows the schedule of planetary protection related documents. It is intended that the established dates be designated "control items" to be reported in the monthly Project Management Reports. The exact dates consistent with the schedule will be determined in a manner agreeable to both PPO and Project Management and will be documented in the Planetary Protection Plan.

Table 5. Planetary Protection Documentation Schedule

Report	Required Schedule

Mission Certification	Request for certification to PPO no later than end of Phase A.
Planetary Protection Plan	Project-approved draft complete no later than end of Project's Conceptual Study Phase (Phase B). Release no later than Project's Preliminary Design Review (PDR).
Subsidiary Plans	Project-approved draft no later than 3 months after completion of draft Planetary Protection Plan. Release of all Subsidiary Plans before, or in conjunction with, the Project's Critical Design Review (CDR).
Certification for "Unrestricted Earth return"	No later than the end of Phase A.
Pre-Launch Planetary Protection Report	No later than 90 days prior to the scheduled launch.
Extended Mission Planetary Protection Report (if applicable)	No later than 60 days prior to scheduled end of the mission per the Planetary Protection Plan.
Post-Launch Planetary Protection Report	No later than 60 days after actual launch.
Earth Pre-Return Report	Release prior to the Earth Return Pre-Launch Review.
Earth Pre-Entry Report	Release prior to the Earth Safety Analysis Review.
End-Of-Mission Report	No later than 60 days after the formally declared "End-of-Mission."
Sample Pre-Release Report (may be released in sections)	Release prior to the Returned Sample Release Review and any release of sample material.

2.6.1. Reviews

A summary of the required review schedule is presented in Table 6.

Table 6. Planetary Protection Review Schedule

Review	Schedule
Planetary Protection Plan	Review within 60 days of draft release.
Subsidiary Plans	Review within 60 days of draft release.
Pre-Launch Planetary Protection Review	No later than 90 days or earlier than 120 days prior to earliest scheduled launch date.
Launch Readiness Review	Project scheduled review.
Earth Return Pre-Launch Review	No earlier than 30 day or later than 7 days prior to earliest scheduled return launch date.
Earth Safety Analysis Review	No earlier than 30 days or later than 7 days prior to commencement of Earth-commit trajectory.

Returned Sample Release Review (may be done in separate segments)	Following completion of the life detection and biohazard testing prescribed by the planetary protection protocols and prior to release of sample material from containment.

CHAPTER 3. Planetary Protection Constraints

3.1 General

The following planetary protection constraints, as may be applicable to each mission, are required. Specific exceptions to these constraints may be requested by a flight project in accordance with the provisions of 2.4 - Request for Deviations.

3.1.1 Specification of Parameters

a. In order for a flight project to demonstrate compliance with planetary protection requirements, appropriate mission specific parameters and specifications (such as the microbial burden requirement for a mission type to a given target planet) will be specified by the PPO at the initiation of the project. Each major parameter and specification will be defined and its value specified on a "Parameter Specification Sheet" which shall be valid when dated and signed by the PPO. Flight projects may use applicable values specified therein without further authorization. Deviations from specified values shall be handled per 2.4. All approved planetary protection parameter specifications are included in Appendix B.
b. The values adopted by a project for undesignated parameters and specifications are subject to the approval of the PPO. These project-developed parameters and specifications will appear in the "Planetary Protection Plan" with later changes reflected in the "Pre-Launch Planetary Protection Report." Approval of these documents will constitute approval of the parameters and specifications contained therein. Alternatively, a project manager may request that the PPO issue appropriate Parameter Specification Sheets based on submitted new information and data.
c. In addition to the primary purpose of designating parameters and specifications used in mission planning, Parameter Specification Sheets also may be used for other purposes, such as defining contamination-related process parameters (e.g., minimum temperature for microbial reduction processes, etc.).

3.1.2 Microbial Reduction

3.1.2.1 Microbial Reduction for Planetary Spacecraft (Including Capsules and Probes) - Post Assembly

a. Microbial reduction for an entire planetary spacecraft (including planetary entry probes and planetary landing capsules) may be accomplished by any approved process. Currently, the only approved method for actively reducing spacecraft to near sterility levels is through the application of dry heat per the appropriate specifications in Appendix B.
b. Alternate methods of microbial reduction may be proposed, such as by chemical or radiation techniques or various combinations of these techniques with heat. Approval of such methods will be based on a rigorous examination of supplied data which must demonstrate conclusively the biological effectiveness and reproducibility of the alternate method for the specific application under consideration.
c. In no case shall basic parameters of microbial reduction processes (e.g., temperature, radiation type, etc.) be made binding in contractual instruments or governing project documents without documented approval of these parameters by the PPO. Usually the specification of these basic parameters will be made in (1) the Microbial Reduction Plan, (2) Parameter Specification Sheets, or (3) contractor-prepared documents submitted for project approval. Approval of these documents by the PPO will constitute approval of the parameters.

3.1.2.2 Microbial Reduction Calculations

a. Validity of Parameter Values

   Parameter values, other than those specified in applicable Parameter Specification Sheets, that are used in calculating microbial reduction process cycles shall be supported by data from reproducible laboratory tests or by suitable technical references.

b. Estimation of Surviving Microorganisms

A calculation of the microbial reduction produced by a given process shall demonstrate that the predicted number of microorganisms surviving the process does not exceed the acceptable value given in the "Pre-Launch Planetary Protection Report."

c. Microbial Reduction Temperature Constraints

For those microbial reduction process cycles that use transient temperature lethality effects, the "dry heat" temperature used to begin lethality calculations shall be as stated in a Parameter Specification Sheet. The minimum steady-state temperature of the dry heat cycle shall not be less than that specified in either the approved Microbial Reduction Plan or in a Parameter Specification Sheet.

3.1.2.3 Verification of Microbial Reduction

Verification that a spacecraft has achieved the required degree of microbial reduction shall not require microbiological assay of the interior of the spacecraft subsequent to the application of the microbial reduction process. Each spacecraft will be considered to have met its microbial reduction requirement provided that the following occur:

a. Approved microbial reduction processes were used.
b. The microbial burden of the spacecraft prior to the application of the microbial reduction process has been estimated (by a means acceptable to the PPO) to be within limits that will allow the planned microbial reduction process to be adequate.
c. It has been verified and documented that the specified microbial reduction process parameters, such as time, atmospheric composition (including water vapor), and temperature, have been properly imposed on the spacecraft.

3.1.2.4 Microbial Reduction of Planetary Spacecraft Parts, Components, and Subsystems Prior to Spacecraft Assembly

It may be desirable to subject either all or certain elements of the spacecraft hardware to a microbial reduction process prior to their assembly. The microbial reduction of such hardware may be accomplished by methods other than those used for the entire spacecraft provided that the following occur:

a. A statement is made in the Microbial Reduction Plan that unique microbial reduction techniques or processes different from those applied to such hardware during the microbial reduction of the entire spacecraft will be used.
b. Each unique microbial reduction technique or process cycle is described in a process specification that includes the biological qualification and quality assurance requirements applicable to the process.
c. Each unique microbial reduction technique or process cycle is approved by the PPO.
d. The microbial reduction process specification to be used on an individual item of hardware must be cited in its detailed engineering specification, as an applicable document.
e. The unique microbial reduction techniques or process cycles employed do not degrade the ability of the spacecraft to withstand the standard "dry heat" or other approved process cycles to be applied to the entire spacecraft.

3.1.2.5 Use of Microbial Barriers to Prevent Recontamination

a. Preplanned operations involving the use of microbial barriers after microbial reduction processes have been conducted may be proposed as part of the Planetary Protection Plan or Subsidiary Plans. If the use of microbial barriers is proposed, the appropriate plan shall describe the operation and qualification of both the hardware and techniques to be used. The following constraints apply to the design and operation of spacecraft microbial barriers:

1. Microbial barriers that are continuously maintained at a static pressure of at least 1244 Pascals (9.3 Torr; 5 inches of H_2O) above the ambient pressure shall be considered microbiologically sealed. For sample handling systems, lower-pressure differentials may be employed for biological safety cabinets per the regulations of the U.S. Centers for Disease Control and Prevention (Primary Containment for Biohazards: Selection, Installation and Use of Biological Safety Cabinets. 2nd Ed. 2000. http://www.cdc.gov/od/ohs/biosfty/bsc/bsc.htm).
2. Microbial barriers that operate essentially at ambient pressure through the use of microbial filters shall be considered microbiologically sealed if the following occur:

i. The designs of all filter mountings, barrier joints, seals etc., have been tested in accordance with applicable design and test specifications and found capable of retaining 99.97 percent of all particles or organisms greater

than 0.3 um in size.
ii. The filters are High Efficiency Particulate Air Filters ("HEPA Filters") capable of removing 99.97 percent of all particles greater than 0.3 um in size.
iii. All elements of the filter system are procured, installed, tested, inspected, and maintained using appropriate quality assurance provisions.

3.1.3 Microbiology Related Determinations

3.1.3.1 Death Rates of Populations of Microorganisms

Calculations involving the death rates of populations of microorganisms subjected to sterilizing conditions shall be based on a death rate model (kill curve) approved by the PPO.

3.1.3.2 Microbiological Assay

a. The procedures used for the microbiological assay of spacecraft hardware and their associated environments shall be as defined in the current version of NPR 5340.1, "NASA Standard Procedures for the Microbiological Examination of Space Hardware," as modified and supplemented by the project's "Microbiological Assay Plan." The approval and use of alternative assay procedures consistent with mission and life detection objectives may be proposed to the PPO by the Project Manager.
b. The following paragraphs describe required microbiological assays:

1. In addition to those microbiological assays which a flight project organization or its contractors may wish to conduct, various verification assays (see Chapter 5) will be conducted for the PPO by an organization designated by the PPO. Verification assays may be observed by involved flight project and contractor organizations.
2. Microbial samples taken from spacecraft hardware, the assembly facility environment, etc. shall be furnished to the PPO by the flight project (or contractors) in accordance with the quantity and locations identified in the Microbiological Assay Plan. Collection of microbiological samples may, at the option of the PPO, be subject to observation by the PPO or his/her designated representative. Microbiological samples will be processed by the organization designated by the PPO to obtain pertinent data (e.g., microorganism types and numbers).
3. In the event that data are suspect due to possible laboratory contamination, an Assay Review Board, appointed by the PPO, shall be formed to review the suspect data and their causes. This Board shall be chaired by the PPO (or designee) with members representing both the organization conducting the assay and the involved flight project and such other members designated by the PPO to provide technical adjudication of the matter. The Board shall present its findings and conclusions to the PPO together with appropriate recommendations.

3.1.4 Launch and Post-Launch Operations (Categories III-V)

3.1.4.1 Launch Operations Constraints

To assure that planetary protection requirements are met throughout launch operations, and until the spacecraft leaves the atmosphere, the PPO (or designated representative) will be present at the launch site during launch operations. As a part of launch operations, the PPO shall verify that planetary protection requirements have been met and that the mission may be launched. To provide a basis for this judgment, the project shall make available to the PPO pertinent information and documentation generated since the Pre-Launch Planetary Protection Review and the Launch Readiness Review as well as real-time information relevant to planetary protection aspects of launch operations.

3.1.4.2 Post-Launch Changes

Changes from the original mission plan that become necessary as a result of post-launch anomalies shall be approved by the PPO before implementation if such changes potentially could affect compliance with planetary protection requirements (also see 2.4.b).

CHAPTER 4. Management

4.1 Project Plan

The management relationships established for the conduct of a specific planetary flight project shall be as described in the applicable Project Plan. Each planetary flight mission Project Plan will be reviewed by the PPO to ensure that management relationships permit the Associate Administrator for the Science Mission Directorate to fulfill his/her responsibilities, as identified in NPD 8020.7.

4.2 Delegated Responsibilities of the Planetary Protection Officer

The responsibilities delegated by the Associate Administrator for the Science Mission Directorate to the PPO are identified in NPD 8020.7. In discharging those responsibilities, the PPO will:

a. Represent the Associate Administrator for the Science Mission Directorate in external technical activities in the area of planetary protection. This includes consultation with other U.S. Government agencies, with representatives of other nations, and coordination with international bodies such as the Committee on Space Research of the International Council for Science.
b. Maintain liaison with the secretariat and members of the Space Studies Board of the National Research Council to formally advise them of NASA planetary protection policy and major actions and to seek their advice and counsel.
c. Establish planetary protection requirements applicable to each planetary flight program/project; coordinate and interpret these requirements with appropriate representatives of the planetary flight program and project offices; establish methods to verify that planetary protection requirements have been met.
d. Provide support to planetary flight program/project offices in the following areas, as may be agreed to by the appropriate flight program and project managers and the PPO:

1. Preparing guidelines, reviewing procedures, interpreting planetary protection documents when necessary, clarifying requirements, and other such information that may be useful to the flight program/project in meeting planetary protection requirements.
2. Reviewing, concurring, or approving procedures, standards, specifications, and other documents used to control factors impacting planetary protection.
3. Providing for the performance of biological assays to supplement those performed by a flight program/project, if applicable.
4. Coordinating closely with flight program/project managers and providing recommendations and guidance as required.

e. Providing oversight of flight program/project activities as required to ascertain the extent of flight program/project adherence to established planetary protection requirements. This may involve the following:

1. Performing verification assays of environments, facilities, and flight hardware independent of assays conducted by flight programs/projects.
2. Monitoring activities and reviewing records and data generated by a flight program/project which are used to verify compliance with planetary protection requirements.
3. Observing significant development and qualification tests and flight program/project operations to verify conformance with approved procedures and plans.

f. Establishing and supporting research and technology development so that state-of-the-art methodologies are incorporated into the implementation of planetary protection policy.

CHAPTER 5. Glossary

Assay (also referred to as "bioassay"). Any activities related to gathering of microbial data through the use of appropriate sampling techniques (swabs, wipes or other approved methods) to obtain microbial samples in order to estimate the number or types of microorganisms associated with an item of interest.

Biological Monitoring. The data management and visual surveillance activities that are performed so that the microbial burden of an item of interest may be verified.

Constraints. Bounding conditions governing aspects of the implementation of planetary protection requirements.

Encapsulated Burden. Microbial burden buried inside nonmetallic spacecraft material.

Exposed Surface. Those surfaces whose microbial burden will likely reach a planetary environment following the nominal landing of a spacecraft. For dry heat considerations, a surface that is free for gas exchange.

Mated Surface. Surfaces joined by fasteners rather than by adhesive.

Microbial Barrier. A means to protect a spacecraft or associated component(s) against microbial recontamination following the application of microbial reduction procedures.

Microbial Burden (also referred to as "Biological Burden" or "Bioburden"). The level of microbial contamination (total number of microbes, spores and non-heat shocked, or microbial density) in or on an item of interest.

Microbial Burden Density. Surface burden density - number of microbes per unit surface area. Volume burden density - number of microbes per unit volume (of non-metallic material).

Microbial Monitoring. The collection, analysis, and associated activities that are performed to verify the biological condition of an item of interest.

Microbial Reduction (also referred to as "Bioburden Reduction"). Any activities designed to remove or destroy microbes that are performed in order to reduce microbial burden levels on or in an item of interest.

Organics Archive. A stored collection of bulk organic constituents (materials) of all launched hardware.

Organics Inventory. An itemized list of bulk organic materials used in launched hardware.

Planet (or "Target Body"). As used in this document, the term includes major planets, planet satellites, and other solar system objects that may be of scientific interest.

Planetary Protection. The protection of a planet from terrestrial contaminants and the protection of the Earth's biosphere from potentially harmful extraterrestrial material.

Release (of a document). The internal (NASA) and external distribution of a document following the affixation of all required signatures.

Spore (or endospore). A structure formed by the actively growing (vegetative) stage of some bacteria that is able to remain viable under extremely harsh environmental (heat, dryness, radiation) conditions and, when the environment improves, once again actively grow and proliferate. As used in this document and in the appropriate requirements and specifications, spore refers to a heat shock surviving microbe culturable in the NASA standard assay.

Sterilization. As used in this document, the process of actively reducing the microbial burden on flight hardware so that the hardware is nearly free (consistent with the appropriate specifications) of all living microorganisms.

Terminal Microbiological Assay. The last assay done prior to terminal sterilization.

Terminal Sterilization. A final sterilization process applied to the entire spacecraft system.

Total Microbial Burden: Total of exposed, mated, and encapsulated microbial burden.

Verification Assay. A microbiological assay performed as requested and directed by the PPO to verify compliance with planetary protection requirements.

Appendix A. Detailed Planetary Protection Requirements

Table of Contents

A.1 Category-Specific Listing of Target Body/Mission Types (advisory only)

a. Category I: Flyby, Orbiter, Lander: the Earth's Moon; Mercury; Undifferentiated, Metamorphosed Asteroids; others TBD pending National Research Council or other-source recommendations.
b. Category II: Flyby, Orbiter, Lander: Venus; Jupiter (exclusive of its icy moons); Saturn; Titan; Uranus; Neptune; Triton; Pluto/Charon; Kuiper-Belt objects; Comets; Carbonaceous Chondrite Asteroids; others TBD pending National Research Council or other-source recommendations.
c. Category III: Flyby, Orbiter: Mars; Europa; Ganymede; Callisto; others TBD pending National Research Council or other-source recommendations.
d. Category IV: Lander, Probe: Mars; Europa; Ganymede; Callisto; others TBD pending National Research Council or other-source recommendations.
e. Category V: Any Earth-return mission.
"Unrestricted Earth return": the Earth's Moon; Undifferentiated, Metamorphosed Asteroids; Short-period Comets; Solar Wind; others TBD (see 2.2.5).
"Restricted Earth return": Mars, Europa; others TBD (see 2.2.5).

A. 2 Category III/IV/V Requirements for Mars

A.2.1 Category III (Mars Orbiters).

a. Orbiter spacecraft that achieve microbial burden levels (surface, mated, and encapsulated) defined in the specification "Maximum Total Microbial Spore Burden for Category III Missions to Mars" shall not be required to meet impact or orbital lifetime requirements. The microbial burden level requirement for Mars is noted in the specification sheet "Maximum Total Microbial Spore Burden for Category III Missions to Mars." Achievement of these levels will likely require some form of active microbial reduction. Approved bioassays (see NPR 5340.1) are required to establish the microbial burden levels. Assembled spacecraft and all modules that have been bioassayed must be protected against recontamination.
b. Orbiter spacecraft that do not meet the requirements, "Maximum Total Microbial Spore Burden for Category III Missions to Mars," are required to meet a probability of impact requirement of 10-2 for a specified orbital lifetime limit, as noted in the specification "Orbital Lifetime Probability, Mars." Mission compliance with these requirements will consist of probability-of-impact analysis and orbital lifetime analysis. Trajectory biasing may be employed to lower the probability-of-impact of mission hardware, but is not required.
c. For Orbiters that meet orbital lifetime requirements, biological cleanliness is assumed by the use of ISO Class 8 (or Class 100,000 under Fed. Std 209E) cleanrooms and the associated procedures. No additional bioload quantification is generally necessary.

A.2.2 Category IV (Mars Landers)

For Mars Landers, Category IV is subdivided into IVa, IVb, and IVc:

a. Category IVa missions comprise lander systems not carrying instruments for the investigation of extant Martian life. These lander systems are restricted to a total surface microbial burden no greater than Viking lander preterminal sterilization levels (see specification sheet "Maximum Surface Microbial Spore Burden for Category IVa Missions to Mars").
b. Category IVb missions comprise lander systems carrying instruments designed to investigate extant Martian life. For such missions, the following requirements apply:

1. Either the entire landed system must be sterilized to the microbial burden levels defined in the specification sheet "Maximum Surface Microbial Spore Burden for Category IVb and IVc Missions to Mars," or to levels driven by the nature and sensitivity of the particular life-detection experiments, whichever are more stringent.
2. Or the subsystems that are involved in the acquisition, delivery, and analysis of samples used for life detection must be sterilized to burden levels defined in the specification sheet "Maximum Surface Microbial Spore Burden for Category IVb and IVc Missions to Mars" and a method of preventing recontamination of the sterilized subsystems and the contamination of the material to be analyzed is in place.

c. Category IVc missions comprise lander systems that investigate Martian special regions (see definition below). For such missions, whether or not they include life detection experiments, the following requirements apply:

1. Case 1. If the landing site is within the special region, the entire landed system shall be sterilized at least to the burden levels defined in the specification sheet "Maximum Surface Microbial Spore Burden for Category IVb and IVc Missions to Mars."
2. Case 2. If the special region is accessed through horizontal or vertical mobility, either the entire landed system shall be sterilized to the microbial burden levels defined in the specification sheet "Maximum Surface Microbial Spore Burden for Category IVb and IVc Missions to Mars," or the subsystems that directly contact the special region shall be sterilized to these levels and a method of preventing their recontamination prior to accessing the special region shall be provided.

   If an off-nominal condition (such as a hard landing) would cause high probability of inadvertent biological contamination of the special region by the spacecraft, the entire landed system must be sterilized to the Viking post-terminal sterilization microbial burden levels.

A.2.2.1 Definition of a "Special Region"

A Special Region is defined as a region within which terrestrial organisms are likely to propagate or a region which is interpreted to have a high potential for the existence of extant Martian life forms. Given current understanding, this applies to regions where liquid water is present or may occur. Specific examples include but are not limited to:

a. Subsurface access in an area and to a depth where the presence of liquid water is probable.
b. Penetrations into polar caps, or other regions of significant water ice.
c. Areas of hydrothermal activity.

For all subcategories (IVa, IVb, and IVc), the following apply:

1. Achieving the prescribed levels of cleanliness will require contamination control (minimum ISO Class 8, or Class 100,000 under Fed. Std 209E, assembly and attendant procedures), microbiological assays, and maintenance of hardware cleanliness. Contamination control effectiveness must be monitored and demonstrated by periodic assays. These assays must also be employed to determine the hardware microbial burden.
2. When needed to meet the burden requirement specifications, the project must provide the facility and the means to accomplish any required microbial reduction. The facility will be subject to certification and the means of microbial reduction subject to approval and monitoring by the PPO.
3. Dry heat is the approved microbial reduction method, and specifications for its use are provided in Appendix B. Alternative methods may later be certified for this purpose, but they will require a demonstration of effectiveness by the project and the approval of the PPO. Following the final predecontamination (or presterilization) microbiological assays and the microbial reduction procedure (as required), the project must demonstrate that the spacecraft or subsystem(s) are adequately protected against recontamination. This may require the use of a bioshield or shroud. Whatever the means of protection, the project must provide evidence that decontamination requirements are not compromised following terminal treatment.
4. An organics archive is required of the bulk (>1kg) organic constituents of all launched hardware which is intended to directly contact the target planet or which might accidentally do so. Each flight program office will

provide for the collection and storage, for at least 20 years from the launch of the spacecraft, of a 50 g sample of each organic compound whose total amount in a planetary landing system exceeds 25 kg.

A.2.3 Category V (Sample Return Missions from Mars)

The Earth-return mission is classified "Restricted Earth return" and is subject to the following requirements:

a. Unless specifically exempted, the outbound leg of the mission shall meet Category IVb requirements. This provision is intended to avoid "false positive" indications in a life-detection and hazard-determination protocol or in the search for life in the sample after it is returned. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all subsequent Mars missions.
b. Unless the sample to be returned is subjected to an accepted and approved sterilization process, the sample container must be sealed after sample acquisition. A redundant, fail-safe containment procedure with a method for verification of its operation before Earth-return shall be required. For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.
c. The mission and the spacecraft design must provide a method to "break the chain of contact" with Mars. No uncontained hardware that contacted Mars, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the Mars environment shall be provided during sample container loading into the containment system, launch from Mars, and any in-flight transfer operations required by the mission.
d. Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving Mars for return to Earth; and 3) prior to commitment to Earth entry.
e. For unsterilized samples returned to Earth, a program of life detection and biohazard testing or a proven sterilization process shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

A.3 Category III/IV/V Requirements For Europa

A.3.1 Category III/IV (Europa Orbiters and Landers).

Requirements for Europa flyby, orbiter, or lander missions, including microbial reduction, shall be applied in order to reduce the probability of inadvertent contamination of an Europan ocean to less than 1x10-4 per mission. These requirements will be refined in future years, but the calculation of this probability should include a conservative estimate of poorly known parameters and address the following factors, at a minimum:

a. Microbial burden at launch.
b. Cruise survival for contaminating organisms.
c. Organism survival in the radiation environment adjacent to Europa.
d. Probability of landing on Europa.
e. The mechanisms of transport to the Europan subsurface.
f. Organism survival and proliferation before, during, and after subsurface transfer.

Preliminary calculations of the probability of contamination suggest that microbial reduction will likely be necessary for Europa orbiters as well as for landers. This will require the use of cleanroom technology, the cleanliness of all parts before assembly, and the monitoring of spacecraft assembly facilities to understand the bioload and its microbial diversity, including specific problematic species. Specific methods should be developed to eradicate problematic species. Methods of microbial reduction should reflect the type of environments found on Europa, focusing on Earth extremophiles most likely to survive on Europa, such as cold and radiation tolerant organisms.

A.3.2 Category V (Sample Return Missions from Europa)

The Earth-return mission is classified, "Restricted Earth return" and is subject to the following requirements:

a. Unless specifically exempted, the outbound leg of the mission shall meet Category IVb requirements. This provision is intended to avoid "false positive" indications in a life-detection and hazard-determination protocol or in the search for life in the sample after it is returned. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all subsequent Europa missions.
b. Unless the sample to be returned is subjected to an accepted and approved sterilization process, the sample

container must be sealed after sample acquisition. A redundant, fail-safe containment procedure with a method for verification of its operation before Earth-return shall be required. For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.

c. The mission and the spacecraft design must provide a method to "break the chain of contact" with Europa. No uncontained hardware that contacted Europa, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the Europan environment shall be provided during sample container loading into the containment system, launch from Europa, and any in-flight transfer operations required by the mission.
d. Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving Europa for return to Earth; and 3) prior to commitment to Earth entry.
e. For unsterilized samples returned to Earth, a program of life detection and biohazard testing or a proven sterilization process shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

A.4 Requirements For Small Solar System Bodies

A.4.1 Outbound Categorization.

The small bodies of the solar system not elsewhere discussed in this document represent a very large class of objects. Forward contamination requirements for these missions are not warranted except on a case-by-case basis, so most such missions should adhere to Categories I or II requirements.

A.4.2 Sample Return Missions from Small Solar System Bodies

a. Determination as to whether a mission is classified "Restricted Earth return" or not (Category V) shall be undertaken with respect to the best multidisciplinary scientific advice, using the framework presented in the 1998 report of the U.S. National Research Council's Space Studies Board entitled, Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making (SSB 1998). Specifically, such a determination shall address the following six questions for each body intended to be sampled:

1. Does the preponderance of scientific evidence indicate that there was never liquid water in or on the target body?
2. Does the preponderance of scientific evidence indicate that metabolically useful energy sources were never present?
3. Does the preponderance of scientific evidence indicate that there was never sufficient organic matter (or CO2 or carbonates and an appropriate source of reducing equivalents) in or on the target body to support life?
4. Does the preponderance of scientific evidence indicate that subsequent to the disappearance of liquid water, the target body has been subjected to extreme temperatures (i.e., >160 C)?
5. Does the preponderance of scientific evidence indicate that there is or was sufficient radiation for biological sterilization of terrestrial life forms?
6. Does the preponderance of scientific evidence indicate there has been a natural influx to Earth, e.g., via meteorites, of material equivalent to a sample returned from the target body?

   For containment procedures to be necessary ("Restricted Earth return"), an answer of "no" or "uncertain" must be returned to all six questions.

b. For missions determined to be Category V "Restricted Earth return" the following requirements shall be met:

1. Unless specifically exempted, the outbound phase of the mission shall meet contamination control requirements to avoid "false positive" indications in a life-detection and hazard-determination protocol, or in the search for life in the sample after it is returned.
2. Unless the sample to be returned is subjected to an accepted and approved sterilization process, the sample container must be sealed after sample acquisition. A redundant, fail-safe containment with a method for verification of its operation before Earth-return shall be required. For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.
3. The mission and the spacecraft design must provide a method to "break the chain of contact" with the small body. No uncontained hardware that contacted Europa, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the body's environment shall be provided during sample container loading into the containment system, launch from the body, and any in-flight transfer operations required by the mission.

4. Reviews and approval of the continuation of the flight mission shall be required at three stages: a) prior to launch from Earth; b) prior to leaving the body or its environment for return to Earth; and c) prior to commitment to Earth entry.
5. For unsterilized samples returned to Earth, a program of life detection and biohazard testing or a proven sterilization process shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

A.5 Additional Implementation Guidelines for Category V Missions

If during the course of a Category V mission there is a change in the circumstances that led to its classification, or a mission failure--e.g., new data or scientific opinion arise that would lead to the reclassification of a mission classified as "Unrestricted Earth return" to "Restricted Earth return," and safe return of the sample cannot be assured, or the sample containment system of a "Restricted Earth return" mission is thought to be compromised and sample sterilization is impossible--then the sample to be returned shall be abandoned. If the sample has already been collected, the spacecraft carrying it must not be allowed to return.

Appendix B: Planetary Protection Specification Sheets

Table of Contents

PARAMETER TITLE: Clean Room Requirement

VALUE	
UPPER	
ACCEPTABLE	Class 100,000/ISO Class 8
LOWER	

APPLICATION	
MISSION	
CATEGORY	III and IV
PLANET	All

PARAMETER DEFINITION: Procedures for spacecraft and payload assembly.

APPLICABLE SOURCE: Spacecraft and payloads.

CONSTRAINTS: All Category III and IV missions shall assemble and maintain spacecraft and payloads in Class 100,000 or ISO Class 8 clean rooms in the operational mode (Ref. 1, 2). The class is to be monitored and verified, with the sampling frequency and number of locations per a clean zone as specified in Ref. 1 or 2 for any flight hardware location within the clean room. Attendant controls and procedures must be similar to those employed by the Viking Project or Ref. 2. This requirement is independent of any other requirement, e.g., any bioburden limitation.

REFERENCES:

1. "Clean Room and Clean Work Station Requirements, Controlled Environments," Federal Standard No. 209E, 1992 (or latest revision).

2. "Cleanrooms and associated controlled environments"
"Part 1: Classification of air cleanliness," ISO 14644-1, 1999.
"Part 2: Specifications for testing and monitoring to prove continued compliance with ISO 14644-1," ISO 14644-2, 2000.
"Part 5: Cleanroom Operations," ISO 14644-5, 2004.

_____ _____
Planetary Protection Officer Date

PARAMETER TITLE: Average Encapsulated Microbial Density { $\bar{d}_v(0)$ }

VALUE	
UPPER	$130/cm^3$
ACCEPTABLE	$130/cm^3$
LOWER	$130/cm^3$

APPLICATION	
MISSION	All
CATEGORY	III, IV
PLANET	All

PARAMETER DEFINITION: The average density of spores buried inside nonmetallic spacecraft material. This value reflects reductions experienced in the manufacture of the basic material but it does not account for any burden reduction during higher level assembly and test.

APPLICABLE SOURCE: Nonmetallic portions of the spacecraft.

CONSTRAINTS: If this parameter is used, it must be applied to the total volume of non-metallic material and further subdivisions using source-specific density values $\bar{d}_v(0)$ shall not be made.

This value was derived assuming the subsequent use of heat sterilization. If processes are proposed that do not include heat for a Category IV mission, the value must be reassessed to assure its applicability for the proposed usage. It may be used without restriction for Category III mission burden estimates.

REFERENCES: Planetary Quarantine Advisory Panel (PQAP) Review, September 28, 1971, Denver, Colorado.

_____ _____

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PARAMETER TITLE: Source Specific Encapsulated MicrobialDensity {$d_V(0)$}

VALUE	
UPPER	
ACCEPTABLE	See Below
LOWER	

APPLICATION	
MISSION	All
CATEGORY	III, IV
PLANET	All

PARAMETER DEFINITION: The average number of spores buried inside the i^{th} subassembly or component of a spacecraft. The number can be expressed in terms of volume or area according to the application as specified below.

APPLICABLE SOURCE: Non-metallic materials on the spacecraft.

CONSTRAINTS: Source-specific density values can be used only if applied to the entire volume of spacecraft nonmetallic material without resorting to the average density value, $d_V(0)$, for any portion thereof. Values for this parameter must be derived for all applicable sources. Values are selected from the following categories and ranges depending upon the composition of, and manufacturing process for, each designated source:

Encapsulated organisms in:	$d_V(0)$
Electronic piece parts	3-150/cm^3
Other nonmetallic materials	1-30/cm^3
Enclosed surface densities:	
Clean room-highly controlled	0.05-0.5cm^2
Clean room-normal control	0.5-10/cm^2
Uncontrolled manufacturing	10-100/cm^2

In the use of this parameter, a rationale shall be presented for the selection of values less than the maximum of the applicable range specified. This value was derived assuming the subsequent use of heat sterilization. If processes are proposed that do not include heat for a Category IV mission, the value must be reassessed to assure its applicability for the proposed usage. It may be used without restriction for Category III mission burden estimates.

REFERENCES: PQAP Review, September 28, 1971, Denver, Colorado.

Planetary Protection Officer _____ Date _____

PARAMETER TITLE: Surface Microbial Density ($d_S(0)$)

VALUE	
UPPER	
ACCEPTABLE	See Below
LOWER	

APPLICATION	
MISSION	All
CATEGORY	III, IV
PLANET	All

PARAMETER DEFINITION: The average number of spores on any free surface (non-encapsulated) of a spacecraft system, subsystem, assembly or subassembly.

APPLICABLE SOURCE: All fallout burden on the spacecraft (exposed and mated).

CONSTRAINTS: Values of this parameter are selected from the following categories, depending on the manufacturing process and cleaning and contamination control procedures for the designated hardware:

Clean room 10^4 or better - highly controlled	$50/m^2$
Clean room 10^4 - normal control	$5x10^2/m^2$
Clean room 10^5 - highly controlled	$1x10^3/m^2$
Clean room 10^5 - normal control	$1x10^4/m^2$
Uncontrolled manufacturing	$1x10^5/m^2$

For estimating surface densities for vegetative microorganisms (for purposes other than to establish terminal sterilization cycles), multiply the above values by a factor of 10.

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PARAMETER TITLE: Temperature Dependence of D-Value (Z)

VALUE	
UPPER	21 C
ACCEPTABLE	21 C
LOWER	21 C

APPLICATION	
MISSION	All
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: The change in temperature which produces a factor of 10 change in a given D-value.

APPLICABLE SOURCE: All microbial burden subjected to dry heat sterilization cycles.

CONSTRAINTS: Applicable within the temperature range of 104 C to 125 C. Applicable to dry heat sterilization cycles meeting requirements of NPR 8020.12.

REFERENCES:
1. Recommendations of PQAP Subcommittee 1A Resulting from Deliberations on July 25-26, 1968.

_____ _____
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PARAMETER TITLE: D-Value for Microbial Spore Burden on Exposed Surfaces (D_{S125})

VALUE	
UPPER	0.5 hr.
ACCEPTABLE	0.5 hr.
LOWER	0.5 hr.

APPLICATION	
MISSION	All
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: Time required to destroy 90 percent of the microbial spore population on surfaces subjected to sterilizing dry heat at a temperature of 125C at an absolute humidity corresponding to a relative humidity of less than 25 percent referenced to the standard conditions of 0 C and 760 torr.

APPLICABLE SOURCE: All microbial spore populations located on spacecraft "free" surfaces (i.e., such that gas exchange can take place).

CONSTRAINTS: Specified D-value can be applied where sterilization cycle conditions stated in NPR 8020.12C have been met. Thermal response of materials must be considered in design of sterilization cycles. Project must specify method for the measurement of these parameters and make allowances for stabilization times.

REFERENCES: 1. Recommendations of PQAP Subcommittee 1A Resulting from Deliberations on July 25-26, 1968.

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PARAMETER TITLE: D-Value for Microbial Spore Burden on Mated Surfaces (D_{M125})

VALUE	
UPPER	1.0 hr.
ACCEPTABLE	1.0 hr.
LOWER	1.0 hr.

APPLICATION	
MISSION	All
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: Time required to destroy 90 percent of the microbial spore population on mated surfaces of spacecraft subjected to sterilizing dry heat at a temperature of 125 C at an absolute humidity corresponding to a relative humidity of less than 25 percent referenced to the standard conditions of 0 C and 760 torr.

APPLICABLE SOURCE: All spore populations on mated surfaces of spacecraft.

CONSTRAINTS: Specified D-value can be applied where sterilization cycle conditions stated in NPR 8020.12C have been met. Thermal response of materials must be considered in design of sterilization cycles. Project must specify method for the measurement of these parameters and make allowances for stabilization times.

REFERENCES:

1. Recommendations of PQAP Subcommittee 1A Resulting from Deliberations on July 25-26, 1968.

Planetary Protection Officer _____ Date _____

PARAMETER TITLE: D-Value for Encapsulated Microbial Spore Burden (D_{B125})

VALUE	
UPPER	5.0 hr.
ACCEPTABLE	5.0 hr.
LOWER	5.0 hr.

APPLICATION	
MISSION	All
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: Time required to destroy 90 percent of the microbial spore population encapsulated in nonmetallic spacecraft material subjected to sterilizing dry heat at a temperature of 125 C.

APPLICABLE SOURCE: All spore populations buried within non-metallic spacecraft materials.

CONSTRAINTS: Specified D-value can be applied where sterilization cycle conditions stated in NPR 8020.12C have been met. Thermal response of materials must be considered in design of sterilization cycles. Project must specify method for the measurement of these parameters and make allowances for stabilization times.

REFERENCES: 1. Recommendations of PQAP Subcommittee 1A Resulting from Deliberations on July 25-26, 1968.

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PARAMETER TITLE: Minimum Number of Spores per Assay (n_{min})

VALUE	
UPPER	
ACCEPTABLE	$\frac{1}{250}$
LOWER	

APPLICATION	
MISSION	All Requiring Terminal Sterilization
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: The minimum number of spores per surface samples assayed acceptable in determining the minimum terminal sterilization cycle.

APPLICABLE SOURCE: All spacecraft surfaces.

CONSTRAINTS: The number of surface samples obtained per assay will be as specified in individual project microbiological assay plans per NPR 8020.12C. Typically, for spacecraft in the 50 - 500 m^2 range, there will be approximately 250 surface samples (each about 25 cm^2 in area) taken per assay. For this class of spacecraft, if all the surface samples used in the assay are negative, an assigned value shall be used for purposes of determining the minimum terminal sterilization cycle. This assigned value shall be one viable spore per total number of surface samples used in the assay.

REFERENCES: 1. Minutes of Meeting of Viking Terminal Sterilization Process, Martin Marietta Corporation, December 11, 1973, Denver, Colorado.

_____ _____
Planetary Protection Officer Date

PARAMETER TITLE: Fraction of Hardy Organisms and their Survival of Nominal Sterilization Cycles (N_H/N_0)

VALUE	
UPPER	1×10^{-3}
ACCEPTABLE	See Below
LOWER	1×10^{-4}

APPLICATION	
MISSION	Any Requiring Sterilization
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: Hardy (heat resistant) organisms as a fraction of the total spore population on spacecraft surfaces. Survival of the hardy organisms is expressed as the ratio of the hardy organisms surviving a nominal sterilization cycle to the initial presterilization total spore population.

APPLICABLE SOURCE: All microbial spore populations located on spacecraft surfaces.

CONSTRAINTS: Hardy organisms comprise a fraction of 1×10^{-3} of the total spore popu-lation on spacecraft surfaces. For nominal sterilization cycles, i.e., 35-50 hours at temperatures of 111-125 C, the surviving fraction of hardy organisms is 1×10^{-4}. Therefore, in designing or assessing spacecraft sterilization cycles, the logarithmic death-rate model based on the D and Z values provided elsewhere in this specification book should not be used to predict lethality greater than 1×10^{-4} for microbial spore populations on spacecraft surfaces. The model is valid, however, for calculating lethality up to the level of the hardy surviving fraction, which, at 1×10^{-4}, establishes the maximum allowable lethality for the nominal sterilization cycles described above.

REFERENCES:

1. Thermal Resistance of Naturally Occurring Airborne Bacterial Spores. J.R. Puleo, et al., Planetary Quarantine Laboratory, Jet Propulsion Laboratory, 1978, Cape Canaveral, Florida.

2. Statistics of the N_H/N_0 Ratio. Paper presented at the "Hardy" Organisms conference, Ames Research Center, November 1974, by P.D. Stabekis, Exotech Research & Analysis, Inc., Gaithersburg, Maryland.

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Planetary Protection Officer Date

PARAMETER TITLE: Time-Temperature for Absolute Sterility (K (†T))

VALUE	
UPPER	≥ 0.5 sec @ ≥ 500 C
ACCEPTABLE	Same
LOWER	Same

APPLICATION	
MISSION	All
CATEGORY	All
PLANET	All

PARAMETER DEFINITION: The short time-high temperature conditions at which all organisms will be completely destroyed.

APPLICABLE SOURCE: Any source of terrestrial organisms associated with spacecraft hardware. Sources can be encapsulated, mated surface, open surface, or airborne. The temperature must exist at the location of the microbial burden for the required time duration.

CONSTRAINTS: Spacecraft organisms and their associated environment must reach a temperature of at least 500 C and must remain at this temperature for at least one half second. This specification was derived from high temperature sterilization tests of microbial contamination.

REFERENCES:

1. Hoffman, R. K., et al. Thermal Inactivation of Aerosolized *Bacillus subtilis* var. *niger* Spores. Appl. Microbiol. 22(4): Oct. 1971.

2. Recommendations of PQAP, meeting held Feb. 1, 1973, New Orleans, Louisiana.

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Planetary Protection Officer Date

PARAMETER TITLE: Probability of Surface Organisms Surviving Ultraviolet Radiation (P (uv))

VALUE	
UPPER	1
ACCEPTABLE	See Below
LOWER	$< 10^{-4}$

APPLICATION	
MISSION	All
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: Probability that a randomly selected organism exposed to extraterrestrial ultraviolet radiation will survive the dose applicable to the mission specific conditions.

APPLICABLE SOURCE: All organisms exposed to extraterrestrial ultraviolet radiation.

CONSTRAINTS: Selection of a particular value is to be made in two steps as follows:

1. Assuming complete exposure of the microorganisms, i.e., no shielding, P(uv) is determined by the function described below. The value of P(uv) as a function of time is a straight line on a log-log scale. For Martian missions, the line is defined by the following two points:
   (a) P(uv) = 1 for a time of exposure of 1 minute, or less, and
   (b) P(uv) = 1 x 10^{-4} for a time of exposure of 1 hour.
   P(uv) for times of exposure other than the above can be obtained by interpolation or extrapolation of these two points. For distances other than for Mars (1.5 AU.), the time of exposure needed shall be scaled by an inverse square relationship.

2. The value obtained in accordance with the above must be increased to allow for the effects of shielding by structures or by small particles such as dust and debris.

REFERENCES: PQAP Review on January 18-19, 1972 at Cape Canaveral, Florida.

_____ _____
Planetary Protection Officer Date

PARAMETER TITLE: Maximum Probability of Accidental Impact, Category III (P_I, max (III))

VALUE	
UPPER	10^{-2}
ACCEPTABLE	10^{-2}
LOWER	10^{-2}

APPLICATION	
MISSION	Orbiter, Flyby
CATEGORY	III
PLANET	Mars

PARAMETER DEFINITION: The maximum allowable probability of accidental impact of a Category III mission.

APPLICABLE SOURCE: All Category III flyby and orbiter spacecraft and other associated hardware.

CONSTRAINTS: The project will conform to Class 100,000 contamination control . For a Category III orbiter, the value must not be exceeded for the period of orbital lifetime required. Launch vehicles must meet a 10^{-4} requirement.

_____ _____
Planetary Protection Officer Date

PARAMETER TITLE: Orbital Lifetime Probability, Mars

VALUE	
UPPER	See Below
ACCEPTABLE	See Below
LOWER	See Below

APPLICATION	
MISSION	Orbiter
CATEGORY	III
PLANET	Mars

PARAMETER DEFINITION: Maximum probability of impact of Mars by a Mars orbiter, or any subsystems thereof, over a specified orbital lifetime.

APPLICABLE SOURCE: Mars orbiters that do not meet the maximum total spore burden requirement (i.e., with total bioburden in excess of 5×10^5 spores).

CONSTRAINTS: Orbit characteristics shall be such that the $P_{I,}$ max (III) for the mission (10^{-2}) shall be met until twenty years from the launch of the mission. Between 20 and 50 years from launch, the spacecraft shall remain in orbit with an assurance ≥ 0.95.

_____ _____
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PARAMETER TITLE: Maximum Total Microbial Spore Burden for Category III Missions to Mars

VALUE	
UPPER	
ACCEPTABLE	$\leq 5.0 \times 10^5$ spores/vehicle
LOWER	

APPLICATION	
MISSION	Orbiter
CATEGORY	III
PLANET	Mars

PARAMETER DEFINITION: Maximum total spore burden for a Mars orbiter, including all subsystems thereof.

APPLICABLE SOURCE: Mars orbiters that do not meet the "Orbital Lifetime Probability Requirement, Mars."

CONSTRAINTS: The total microbial burden (i.e., spore burden on free surfaces, mated surfaces, and encapsulated in nonmetallic material) for each Category III orbiter shall be $\leq 5.0 \times 10^5$ spores, as measured by microbiological assay processes and techniques used for establishing the burden levels on the Viking landers and orbiters (Ref. 1), or other approved assay methods. It shall be incumbent on the project to demonstrate equivalence for techniques other than those used on Viking.

The microbial burden levels specified apply to spores on the orbiter system at launch. No allowance shall be made for burden reduction factors that may be associated with inflight or surface conditions on Mars (vacuum, UV, temperature, etc.)

This total microbial burden level (surface, mated, and encapsulated) is based on the average total presterilization microbial burden level for the Viking landers.

REFERENCES: 1. Viking '75 Program Microbiological Assay and Monitoring Plan, Viking '75 Project, M75-148-0.

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PARAMETER TITLE: Maximum Surface Microbial Spore Burden for Category IVa Missions to Mars

VALUE	
UPPER	
ACCEPTABLE	$\leq$ 300 bacterial spores/m^2 $\leq 3.0 \times 10^5$ bacterial spores/ vehicle
LOWER	

APPLICATION	
MISSION	Lander, Probe
CATEGORY	IV
PLANET	Mars

PARAMETER DEFINITION: This specification establishes a maximum limit on the exposed surface bioburden for all Category IVa missions to Mars.

APPLICABLE SOURCE: Exposed exterior and interior spacecraft surfaces.

CONSTRAINTS: The surface bioburden for each Category IV probe or lander system, defined as all subsystems included in a single landing event, shall be an average of $\leq$ 300 bacterial spores per square meter and the total vehicle surface burden shall be $\leq$ 3.0×10^5 bacterial spores, as measured by microbiological assay processes and techniques used for establishing the burden levels on the Viking landers and orbiters (Ref. 1), or other approved assay methods. It shall be incumbent on the project to demonstrate equivalence for techniques other than those used on Viking.

The burden levels specified apply to organisms on the orbiter, probe, or lander system at launch. No allowance shall be made for burden reduction factors that may be associated with inflight or surface conditions on Mars (vacuum, UV, temperature, etc.).

These surface microbial burden levels are based on the average presterilization surface microbial burden levels for the Viking landers.

REFERENCES: 1. Viking '75 Program Microbiological Assay and Monitoring Plan, Viking '75 Project, M75-148-0.

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PARAMETER TITLE: Maximum Total Microbial Spore Burden for Category IV Missions to Mars

VALUE	
UPPER	
ACCEPTABLE	≤ 5.0 x 10^5 bacterial spores/ vehicle
LOWER	

APPLICATION	
MISSION	Lander, Probe
CATEGORY	IV
PLANET	Mars

PARAMETER DEFINITION: This specification establishes a maximum limit on the total spore burden for all Category IV missions to Mars.

APPLICABLE SOURCE: Mars landers and probes that have hardware making a planned hard landing and/or have a non-nominal impact requirement.

CONSTRAINTS: The total microbial burden (i.e., spore burden on free surfaces, mated surfaces, and encapsulated in non-metallic material) for each Category IV probe or lander system included in a single landing event, plus any cruise and entry vehicle hardware, shall be ≤ 5.0 x 10^5 bacterial spores, as measured by assay processes and techniques used for establishing the burden levels on the Viking landers (Ref. 1) or other approved methods.

The microbial burden levels specified apply to those subsystems which make a planned hard landing and/or have a non-nominal impact requirement. The 5.0 x 10^5 spores/vehicle includes the 3.0 x 10^5 spores/vehicle allocated to the exposed exterior and interior spacecraft surfaces.

The microbial burden levels specified apply to spores on the lander system at launch. No allowance shall be made for burden reduction factors that may be associated with inflight or surface conditions on Mars (vacuum, UV, temperature, etc.).

This total microbial burden level (surface, mated, and encapsulated) is based on the average total presterilization microbial burden level for the Viking landers. Applies to the presystem/subsystem sterilization cleanliness levels for IVb and IVc missions.

REFERENCES: 1. Viking '75 Program Microbiological Assay and Monitoring Plan, Viking '75 Project, M75-148-0.

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Planetary Protection Officer Date

PARAMETER TITLE: Maximum Surface Microbial Spore Burden for Category IVb and IVc Missions to Mars

VALUE	
UPPER	
ACCEPTABLE	≤ 30 bacterial spores on the free surfaces of a landed system
LOWER	

APPLICATION	
MISSION	Lander, Probe
CATEGORY	IV
PLANET	Mars

PARAMETER DEFINITION: This specification establishes a maximum limit on the free surface bioburden for all Category IVb and IVc missions to Mars.

APPLICABLE SOURCE: All free exterior and interior spacecraft surfaces.

CONSTRAINTS: The surface bioburden for each Category IVb probe or lander system, defined as all subsystems included in a single landing event, shall be ≤ 30 bacterial spores, as established by the application, to a lander meeting Category IVa specifications, of the dry heat microbial reduction process used for the Viking landers, and specified in this document. It shall be incumbent on the project to demonstrate equivalence for other sterilization/decontamination methods. Under special circumstances, this specification's applicability may be limited to selected subsystems for both Categories IVb and IVc.

The burden levels specified apply to organisms on the probe, or lander system at launch. No allowance shall be made for burden reduction factors that may be associated with inflight or surface conditions on Mars (vacuum, UV, temperature, etc.).

This surface microbial burden level is based on the estimated post-sterilization surface microbial burden level for the Viking landers.

REFERENCES: 1. Viking '75 Program Microbiological Assay and Monitoring Plan, Viking '75 Project, M75-148-0.

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Planetary Protection Officer Date

PARAMETER TITLE: Maximum Probability of Contamination of an Europan Ocean

VALUE	
UPPER	
ACCEPTABLE	$\leq 1.0 \times 10^{-4}$
LOWER	

APPLICATION	
MISSION	All
CATEGORY	III and IV
PLANET	Europa

PARAMETER DEFINITION: Maximum probability of contaminating an Europan ocean with terrestrial contamination.

APPLICABLE SOURCE: Europa flybys, orbiters, landers, and probes.

CONSTRAINTS: The probability of inadvertently contaminating an Europan ocean shall be less or equal to 1.0×10^{-4} per mission. The calculation of this probability should include a conservative estimate of poorly known parameters and address the following factors, at a minimum:

(1) Microbial burden at launch.

(2) Cruise survival for contaminating organisms.

(3) Organism survival in the radiation environment adjacent to Europa.

(4) Probability of landing on Europa.

(5) The mechanisms of transport to the Europan subsurface.

(6) Organism survival and proliferation before, during, and after subsurface transfer.

REFERENCES:

1. Space Studies Board, National Research Council, *Preventing the Forward Contamination of Europa*, National Academy Press, Washington, D.C., 2000.

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